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SPATIAL AND TEMPORAL ANALYSIS OF TEMPERATURE FOR THE STATE OF KARNATAKA, INDIA

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ABSTRACT

The present study was carried out to examine the spatial and temporal variability trends in mean temperature at annual and seasonal basis for the 24 districts of Karnataka state, India. Statistical trend analysis techniques, namely the Mann–Kendall test and Theil-Sen slope estimator test were used to examine trends in temperature at the 5% level of significance (LOS). The mean temperature for the pre-monsoon, monsoon, post-monsoon, winter and annual increased by 0.61, 0.21, 0.66, 0.45and 0.29^{0}C respectively over the past 102 years during (1901-2002) in the study area. Magnitude of trend variation for mean temperature was dominant in pre-monsoon and winter seasons for the state of Karnataka. In addition, the increasing trend of annual mean temperature increased with latitude in the study area. But for the seasonal basis, severity of increasing trend of temperature varied with seasons.

KEYWORDS: Mann-Kendall Test, Temperature, Climate Change

INTRODUCTION

Temperature is the second most important meteorological variable after precipitation because it can be related to solar radiation and thus with both evaporation and transpiration processes which constitute an important phase of the hydrologic cycle.In the most recent studies it is observed that significant warming in the second half of the 20thcentury resulted in a drastic change in the hydrology of an agricultural based country like India (IPCC, 2013). Magnitude and trend of warming of India during the last century over Indian continent is matching with the global condition (Pant and Rupa Kumar, 1997).

Hydrologic variables (evaporation, precipitation, runoffetc.) are directly or indirectly dependent on atmospheric variables (pressure, humidity, temperature, precipitable water etc.).Among the various dominant atmospheric variables, temperature has a significant and direct influence on almost all hydrological variables. As the temperature increases, the relative humidity usually decreases and vice versa. Evapotranspiration is affectedby weather parameters and crop growth dynamics. Increase in temperature leads to increase in demand of crop water and decrease in its supply. Spatial pattern, temporal pattern and variability of surface temperature plays a vital role in modeling miscellaneous processes in hydrology, climatology, agriculture, environmental engineering, and forestry both at local and global levels.

From the past study it was found that in the last century, Indian subcontinent has experienced increasing trend in temperature but the magnitude is varying with seasons (Arora et al, 2005, IPCC, 2013, Santosh Pingale et al, 2012, Pant and Rupa Kumar, 1997).Under a warmer climate, the arid and semiarid region like Karnataka could experience severe water stress due to the decline in soil moisture. Agriculture is the mainstay of the State’s economy as it provides 70% of employment. Since the agricultural productivity is likely to suffer severely due to higher temperatures and no study was found in literature on spatial and temporal variability of temperature at Karnataka, the aims of this study is to investigate the spatial and temporal variability oftemperature of this region.

MATERIALS & METHODS

Karnataka is located on the western coast of peninsular India, enclosed between 11.50 ^{0}N to 18.50 ^{0}N and 74 ^{0}E to 78.5 ^{0}E. Geographical area of Karnataka is about 191791 square kilometers, comprising of 30 districts “Figure 1”. Geographical zones of Karnataka are broadly categorized into three types; Coastal region, Western Ghats region and Deccan plateau (transition zone and dry zone). The highest and the lowest temperature recorded in the state were 45.6 ^{o}C (May 23, 1928) and 2.8 ^{o}C (December 16, 1918) at Raichur and Bidar, respectively.

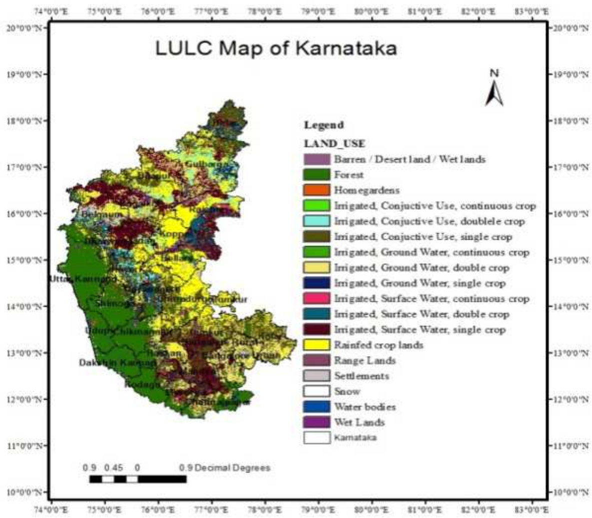

Figure 1: Geographical Map of Karnataka

Monthly mean temperature of 24 districts data for the period of 102 years (1901-2002) downloaded from India water portal site (http://www.indiawaterportal.org). The spatial and temporal variability of temperature was studied at annual and seasonal basis (pre-monsoon, monsoon, post-monsoon and winter) with statistical analysis. Further, study was carried out at different time periods 1901-1940, 1941-1980, 1981-2002 and 1901-2002 for mean temperature.

Mann–Kendall Test

The Mann–Kendall (MK) test is a non-parametric test that can be used for detecting trends in a time series (Mann, 1945) where autocorrelation is non-significant. It has been found to be an excellent tool for trend detection to assess the significance of trends in hydro-meteorological time series data such as water quality, stream flow, temperature and precipitation (SantoshPingale et. al 2012). The M-K test can be applied to a time series x_i ranked from i = 1, 2, 3 … n - 1 and x_j ranked from j = i + 1, 2, 3 … n such that:

$$\text{Sgn}(x_j - x_i) = \begin{cases} 1 \text{ if } (x_j - x_i) > 0 \\ 0 \text{ if } (x_j - x_i) = 0 \\ -1 \text{ if } (x_j - x_i) < 0 \end{cases} \quad (1)$$

The Kendall test statistic S can be computed as:

$$S = \sum_{k=1}^{n-1} \text{Sgn}(x_j - x_k) \quad (2)$$

Where $\text{sgn}(x_j - x_k)$ is the signum function. The test statistic S is assumed to be asymptotically normal, with $E(S) = 0$ for the sample size $n \geq 8$ and variance as follows:

$$\text{Var}(S) = \frac{[n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)]}{18} \quad (3)$$

Where t_i denotes number of ties up to sample i .

The standardized M-K test statistic (Z_{mk}) can be estimated as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} \text{ if } S > 0 \\ 0 \text{ if } S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}} \text{ if } S < 0 \end{cases} \quad (4)$$

The standardized MK test statistic (Z_{mk}) follows the standard normal distribution with a mean of zero and variance of one. The presence of a statistically significant trend is evaluated using the Z_{mk} value. A positive (negative) value of Z_{mk} indicates an increasing (decreasing) trend. If $\pm Z_{mk} \leq Z_{\alpha/2}$ (here $\alpha = 0.1$), then the null hypothesis for no trend is accepted in a two sided test for trend, and the null hypothesis for the no trend is rejected if $\pm Z_{mk} \geq Z_{\alpha/2}$. Failing to reject H_0 (i.e, null hypothesis) does not mean that there is no trend.

The magnitude of trend was studied by using Theil- Sen’s slope estimator test (1950). The magnitude of slope is computed as:

$$Q = \text{median}\left(\frac{X_j - X_k}{j-k}\right) \text{ for all } k < j \quad (5)$$

Where X_j and X_k are data at points j and k respectively. For the n number of data points, estimated slope is n(n-1)/2 and statistic value Q is the median of all estimated slope. The positive and negative values of Q indicates increasing and decreasing trend respectively.

RESULTS

The study area was classified based on the annual mean and seasonal variation of temperature for better representation of temperature fluctuation at different zones. In the Karnataka state the temperature fluctuated from a minimum of 14^0 C during winter season to a maximum of $42\ ^0$ C during summer season. Temperature varied from one place to another place depending upon its geography. In this study, based on temperature, Karnataka state was broadly categorized into three zones; low (<26 ^{0}C), moderate (26-32 ^{0}C) and high temperature zone (>32 ^{0}C).

The Mann-Kendall test results for the mean temperature are shown in figures 2-6. The Analysis showed that there was no trend in temperature at 5% significance level for annual and seasonal temperature at all 24 districts of the study area during the period of 1901-1980. Further, during the period 1901-1940 no trend was shown but values of Z for

Mann-Kendall test showed negative for most of the districts. Negative values indicated that there was negative trend in the temperature at alternative hypothesis. Trend shift in mean temperature was observed after 1980 in the districts of Bangalore Rural, Bangalore Urban, Chamarajanagaraand Kolarof the study area. On seasonal basis, monsoon, post-monsoon and winter seasons were the dominant season of increasing trend in temperature during the period of 1980-2002. While for the period during 1901-1980, the severity of trend was strong in the pre-monsoon and monsoon seasons but not at 5% significance level over the study area. For the period during 1901-2002 i.e. during the last 102 years there was a significant increase in temperature in the study area. This increase in trend for annual mean temperature increased with latitude over the study area “Figure 2”.

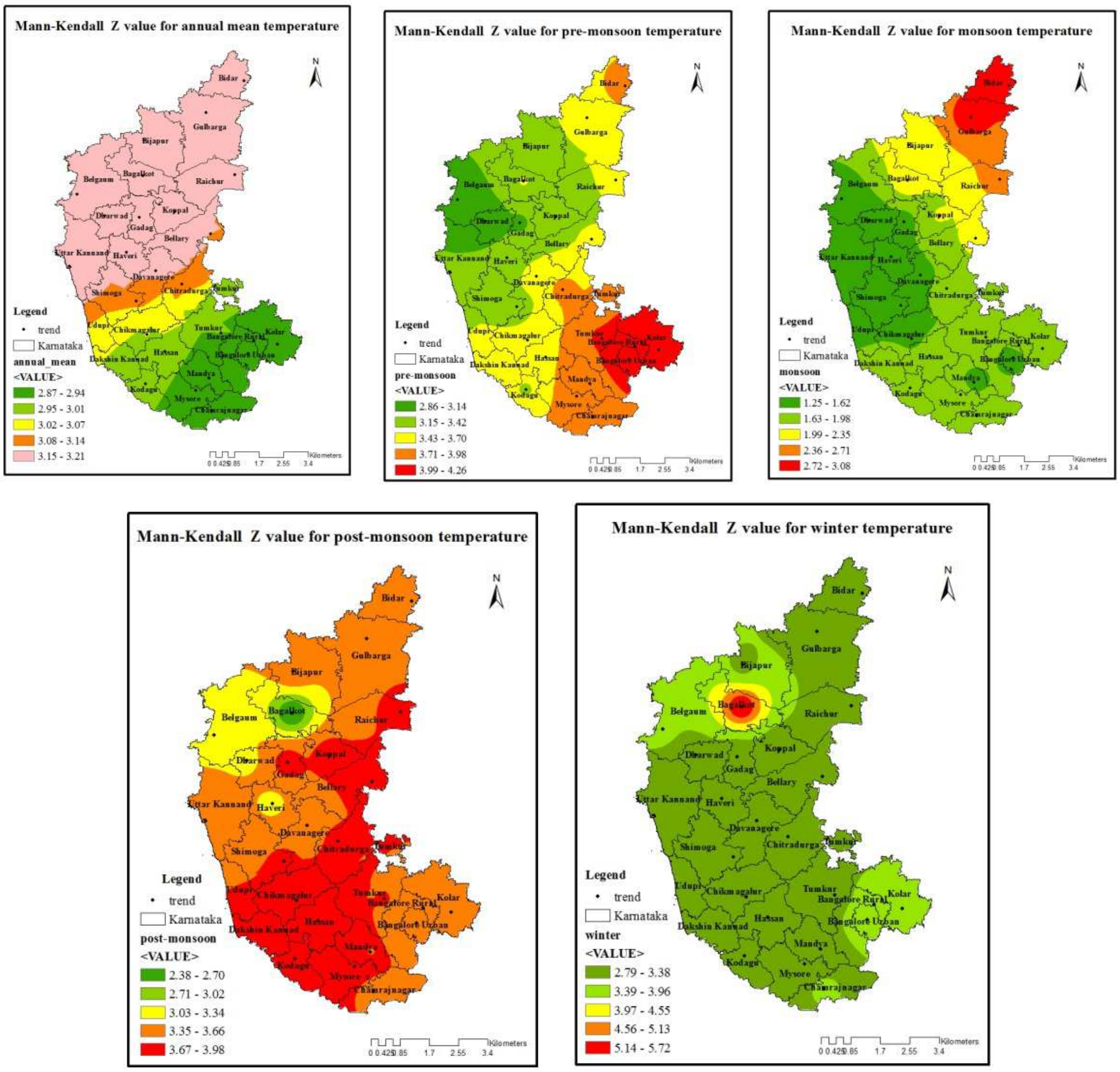

Figure 2, 3, 4, 5, 6: Annual Mean, Pre-Monsoon, Monsoon, Post- Monsoon and Winter Season Temperature Mann-Kendall Z Value Variation

The magnitude of trend in annual mean temperature was not significant during the period of 1901-1940 because it ranged between 0.001 to -0.001 ^{0}C mm/hydrologic year and for the most of the districts magnitude of trend was negligible. At seasonal basis, post-monsoon season was dominant season for decrease in trend of temperature as the magnitude ranged between -0.001 to -0.010 ^{0}C mm/hydrologic year. These decreases in magnitude of trend were dominant in the high temperature zone than the moderate and low temperature zone. The magnitude of trend in temperature increased in the

period during 1941 to1980 and it extended its severity in the period during 1981-2002. The magnitude varied between 0.005-0.022, 0.0051-0.020, 0.0026-0.031 and 0.0025-0.021 ^{0}C mm/hydrologic year for the pre-monsoon, monsoon, post-monsoon and winter seasons respectively during the period of 1941-2002.

In long term i.e. for the period of 1901-2002, the magnitude of trend in annual mean temperature varied between 0.003 to 0.012^{0}C / hydrologic year in the study area. The maximum increase in the magnitude of trend was observed in the high temperature zone i.e. in the Bagalakot, Bidar, Bijapur, Bellay, Gulbarga, Koppal and Raichur districts. The magnitude of trend was smallest at districts under Western-Ghats. The magnitude of increase in temperature was robust in all seasons excluding monsoon season. The mean temperature increased by 0.61, 0.21, 0.66, 0.45and 0.29^{0}C for the pre-monsoon, monsoon, post-monsoon, winter and annual mean temperature respectively over the past 102 years in the study area.

CONCLUSIONS

The mean air temperature had increased by 0.61, 0.21, 0.66, 0.45and 0.29^{0}C for the pre-monsoon, monsoon, post-monsoon, winter and annual mean temperature respectively over the past 102 years. In the period during 1901-1940 there was no trend in temperature at 5% significance level for annual and seasonal temperature at all 24 districts of Karnataka state. But the values of Z for Mann-Kendall test had shown negative for most of districts, which indicatedthe negative trend in the temperature at alternative hypothesis. Similar trend had been shown by Santosh Pingale et al, 2012, during less urbanized period (1901-1951). Furthermore, the magnitude of trend in temperature has increased during the period of 1941 to1980 and it extended its severity during the period of 1981-2002. Major increase in trend was found in the pre-monsoon and winter seasons on seasonal basis and for the annual basis a significant trend was observed in the most of the districts (Arora et al, 2005, IPCC, 2013, Santosh Pingale et al, 2012, Pant and Rupa Kumar, 1997). Analysis showed that increase in trend for annual mean temperature was correlated with an increase in latitude.

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